LECTURES

ON

THE FORMATION AND EARLY GROWTH
OF THE BRAIN OF MAN.*Delivered at the Royal College of Surgeons of England.*

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LECTURE I.

I PROPOSE to describe the general plan of the formation and early growth of the brain of man—a subject which I trust will be considered to fall within the scope of the objects for which these lectures were instituted.

The subject is one of practical interest to all surgeons; for we are often called upon to diagnose and to treat injuries of the nerve-centres which collectively constitute the brain (by which term, it may be stated once for all, that those structures are indicated which lie above a horizontal line drawn through the foramen magnum in the erect position of the subject); and of late years our attention has been especially attracted to the possibility of our being able to localise with considerable accuracy the seat of some of these injuries by the recognition of specific symptoms. And, although there may be little prospect of our being helped by such knowledge to a more successful treatment of these hurts, yet, through a more precise diagnosis we certainly obtain the advantage of greater accuracy in our prognosis; and, further, we may be enabled to throw some light upon the relations which subsist between various brain-regions and varied life-functions; and this is alone a subject of such broad and high interest as must always possess, for those who practise our profession, attractions of the very first order.

The work by which this greater sureness in diagnosis has been aimed at, has been carried on in two directions: in one, by making experiments upon the lower animals, from which experiences it would seem that specific regions of the brain are in relation with the discharge of certain definite manifestations of life—experiences as to questions of fact, which need careful and independent repetitions before they can be accepted as conclusive; in another direction, by clinical observations of the life-symptoms which are associated with disorganisation or irritation of particular brain-districts. Amongst such may be named, merely in illustration, the symptoms of aphasia following injury of a part of the left hemisphere outside the corpus striatum; and the evidence which I brought forward, and which is confirmed by the experience of Dr. Brown-Séquard (*Archives of Scientific and Practical Medicine*, March 1873, p. 264), to show that injuries to the right hemisphere are more rapidly fatal than are equal injuries to the left; and, further, that the right side brain-lesions are more often associated with convulsions than are similar hurts on the opposite side.

In working in either of these directions, however, some difficulty is met with, owing to the uncertainty which exists as to the precise relations one to another of the various parts of the brain; and although, no doubt, physiological research will have to be chiefly relied upon in clearing up these uncertainties, yet I think it may at least help to facilitate investigations as to the functions of the various parts of the brain, if the order of the early growth of its parts be carefully considered. I do not venture to hope that it is possible to give an absolutely definite exposition of the formation of so complicated a structure as the human brain; but there are at least some details on which we may obtain precise information; and there are inferences which may be fairly drawn, when precise information may not be attainable.

In dealing with the subject, the dissections of the brain will be described at several stages of its growth during foetal life; such descriptions being, it may be observed, of facts such as any who will be at the trouble may observe for themselves. As reference must often be made to the precise period of development to which given observations refer, this table will show, with sufficient accuracy for all practical purposes, the length of a foetus in correspondence with its age; so that, when the length (from vertex to heel) of any specimen is named, a glance at the table will give a close approximation to its age in days and weeks.

TABLE I.

Length of Fœtus, in inches.				Age, in weeks.	Age, in days.
.12	..	..	..	3	7 to 14
.4	..	..	..	6	35 to 42
.5	..	..	..	7	42 to 49
.7	..	..	..	8	49 to 56
.9	}	..	..	9	56 to 63
1.1		..	..	10	63 to 70
1.5	..	..	..	10	63 to 70
2.3	}	..	..	12 to 16	84 to 112
3		..	..		
3.5		..	..		
3.7		..	..		
3.8	}	..	..	16 to 20	120 to 140
4		..	..		
4.3		..	..		
4.7		..	..		
6.5	}	..	..	22 to 24	154 to 163
6.7		..	..		
7		..	..		
9		..	..		
10	..	..	..	22 to 24	154 to 163

I am aware that this table differs somewhat from others which have been published; but it has been prepared from specimens which have been carefully considered, and may be accepted as fairly correct.

It has been my object to work out these dissections unbiassed by the observations of others; for, however valuable are their investigations, it is, I think, important to free oneself as far as possible from lines of thought which have been worked through. And, further, I have abstained from associating this work in any way with that of comparative anatomists. The following remarks apply solely to the human subject. What there is that is exact in them will, no doubt, fit in with what is accurate in investigations conducted on the lower animals; but the common goal should be gained by independent approaches. Indeed, were my wishes otherwise, my knowledge of comparative anatomy is not sufficiently great to justify me in moving within its lines.

In explaining the plan of growth of the human brain, it is necessary to refer to the formation of the case which encloses the cerebro-spinal ganglia, and extensions from which protect the cerebral and spinal nerves. Most of the steps in the development of these structures are familiar to us through the precise and able demonstrations of them which have been given in this theatre by Professor Huxley. They must, however, be briefly mentioned, to give continuity to the consideration of our subject, and to enable reference to be made to some facts to which attention has to be especially directed.

In the earliest stage of development, when the primitive groove is first seen, there is a rising up of the mesoblast and epiblast to form the dorsal, or, as they may be termed, the axial laminæ, which, by mesial union, complete the axial arches. I prefer the use of this term axial, because it enables us to range as subaxial and as preaxial the various arches which have been grouped hitherto under special titles, as the mandibular and the hyoid, and as the visceral arches. By naming the arches connected with the cranium subaxial, and the remaining arches preaxial (visceral), we obtain a definite series on the one side of the axis cord, as on the other.

The axial (dorsal) arches (Fig. 1 c), slightly dilated towards their lower extremity, are expanded at the superior, and are marked before long by four constrictions, one of which is terminal; and at this end the axial laminæ unite, and close the groove rather earlier than elsewhere. In the intermediate layer which underlies the primitive groove, is the

Fig. 1.

Fig. 2.

axis notochord, of the same length as the groove. At a very early period, it bends forward at its superior extremity (in the human foetus) at a point opposite the second anterior constriction; and with this curve of the notochord, the extremity of the axial arches (which now enclose the cerebro-spinal canal) is flexed nearly to a right angle with the rest, and, growing forward, bulges in front of the extremity of the notochord. This notochord tapers at its superior extremity, and terminates behind the fossa in which the pituitary body is lodged; and it is, it will be

observed, on the tissue which surrounds the end of the notochord, that the anterior portion of the cerebral vesicles now rests.

The anterior dilatations of the cerebro-spinal canal are the parts from which the coverings of the brain and of the cerebral nerves are formed; and the appearance of three dilatations is supposed to be due to the shape assumed by the brain, which now consists of three lobes, commonly called the anterior, middle, and posterior vesicles. As the pituitary gland is found in relation with the end of the notochord, so on the upper surface of the anterior vesicle, or rather on the constriction dividing it from the middle vesicle, is the site of the pineal gland.

The distinction between the spinal and the cranial portions of the axis is marked at a very early period by the appearance of the proto-vertebræ in the anterior portion of the cervical region (fig. 1, s.); and this distinction seems to indicate, although there may be points of resemblance between the cephalic and the spinal divisions of the axis, especially during the first stages of development, yet that a clear line of demarcation is soon drawn between the two. The ring of tissue from which the cephalic development (fig. 1, c.) takes place may indeed be looked upon as the first or highest of the vertebral series, but the changes which this tissue undergoes so modify its characters in correspondence with the great development of the encephalic structures, as to make it evident that the details of its formation do not admit of close comparison with those of the parts of one of the vertebræ.

Another change which occurs at this early period, and which is of some importance, is that of the superior and inferior limitation of the cerebro-spinal axis. At the inferior extremity, the canal is closed by the conjunction of the tissues forming the last axial arch; and, in the subsequent growth of the spinal column in length, the connection between the closed end and the spinal cord is preserved and indicated by the persistence of the filum terminale. Just beyond the end of the notochord, and at the point of closure of the canal, there is found the gland of Luschka. At the superior extremity, the canal is closed by extension of tissue from the upper border of the first, or cranial, axial arch; and the line at which this forward growth takes place corresponds to that of the second cranial constriction, the anterior vesicle being an outgrowth from the axis cylinder; and in the middle line, in front and behind, there is placed beneath the line of closure the pituitary body and the pineal gland (fig. ii, Pt. v.). Beneath the enclosing tissue may be traced the anterior portion of the brain, and on the edges of its side-pieces are the peduncles of the pineal gland. It is known of the pituitary body that it exists, with the infundibulum, from an early period, and both it and the pineal gland, retaining for the present the names usually given to these structures, may be recognised in a foetus one inch long.

There exists, therefore, a marked distinction between the cranial and the spinal portions of the axis from a very early period of their development; and where the axis is limited superiorly are found two remarkable structures, the pituitary and the pineal, on a line between which, from before backwards, the tissue coalesces to close the canal and to cover in and protect the vesicles of the brain.

The tissue in which the development of the skull now proceeds consists of the cartilage (as it presently becomes) which surrounds the end of the notochord, and which is prolonged backwards (after the fashion of an axial arch) to enclose the vesicles as far forward as the line of constriction between the anterior and the middle, and beyond this of the indifferent tissue which develops from this arch to cover in the anterior vesicle, and which rapidly extends forward in correspondence with the growth of the brain in this direction (fig. vii, between Pt. and p.). It is in this tissue that the bones which form the vault of the skull are developed, including the portion of the occipital bone above the level of the internal occipital prominence.

The singular fact that the lower portion of the occipital bone is the only part of the structures forming the vault of the skull developed in cartilage is explained by the relation of this bone to the first axial ring, of which it forms part so far as its occipital prominence (fig. iii, 1. c.), this prominence being the point at which the pineal gland is attached (fig. iii, p.), the gland being developed at the junction of the laminae to form this arch; thus the occipital bone, to the level of its protuberance, is formed in part of the ring of cartilage in which are also formed the bones of the base of the cranium.

Fig. 3.

Fig. 4.

From that portion of the ring of cartilage which surrounds the notochord, here grow out two processes (trabeculae), at first distinct, but soon

curving towards each other and then uniting, before and after doing so throwing up slight elevations of tissue. This is a remarkable disposition, which results in their forming between them a pit or depression surrounded by the four elevations to which the membrane developed with the outgrowth of the two processes is attached. These processes, or trabeculae, when united, extend forward, retaining on their upper surface a mesial groove, which marks their original division (fig. v, 1), and throw down nearly vertical plates, one mesial (the septum nasi), and two lateral (the ethmoidal masses). They terminate in front in the cartilages of the nose and in the intermaxillary bones. These trabeculae are formed in connection with the forward growth of the brain and with the development of the olfactory lobes, the nerves from which find protection within the plates which descend to bound the nostrils.

Before the trabeculae have advanced so far as to complete their descending plates, a growth from the brain on either side has pushed forward the membranous covering of the anterior vesicle. At the same time, two spurs of cartilage grow out from the trabeculae (fig. v, 2, 3), one passing above and the other below the round tubular projection of nerve-tissue. These processes check the outgrowth of the membrane, and cause it to be doubled over so as to make an envelope for the membrane pushed forward by the outgrowing nerve. This, with its membranous covering, is the eye, and the enveloping membrane is part of the orbit. The growth of cartilage about the protruding nerve is the tissue in which the presphenoid and the orbito-sphenoid are ossified, and it springs from the trabeculae just in front of the pit (pituitary fossa).

Whilst these changes provide for the support of the fore-brain, and for the protection of the olfactory and optic nerves, the occipital plates are being deflected backwards (fig. iii, 1. c., and iv, 1. c.), by the development from the basal cartilage of the cartilage for the auditory apparatus, which is thrust out between the sphenoid and exoccipital tissue; thus, too, space is provided for the increase of the middle and posterior vesicles of the brain. By this occipital deflexion, the internal occipital protuberance is seen in a foetus 1.5 inches long, to be moved back from the pineal gland (fig. iv, p.), and, but that its connection with that body is distinct at an earlier period, it would now escape recognition. The two are, however, still united, as will be seen when the relations of the membranes are explained.

In the growth of the periotic mass, and in that of the exoccipital cartilage, provision is made for the passage of the facial, auditory, and hypoglossal nerves, to the exterior of the cranium.

By prolongations of cartilage and of membrane from the basal structures, the various subaxial arches are developed. In a foetus, five-tenths of an inch long, the eye is formed, and the orbit is nearly completed. In the middle line, the cartilage of the trabeculae, as seen on its facial aspect, consists of a shield-like plate (fig. v, 1 i), growing forwards and downwards. This shield supports the anterior lobes of the hemispheres, but it likewise protects the first cerebral or olfactory nerves, and it is consequently convenient to regard it as a mesial and duplicate subaxial arch, the first, or highest, of the series, and bounding by its three plates two clefts, which are also the first on each side, and afford an exit to the nerves from the olfactory lobes, and an area for their distribution. On the outer side of each lateral plate of the subaxial arch, there is, at this stage of development, a cleft, the second in order, (fig v, 2), between it and the membrane which at all other points surrounds the orbit. This membrane is prolonged from the cartilage which has grown out from the trabeculae around the optic and following nerves to the sixth inclusive, and constitutes the second subaxial arch. In this tissue, the malar and the superior maxillary bones are formed, and by the growth from the latter of the nasal process, the second cleft is closed on its inner side, and the orbit, lodging the eye, is completed; whilst, by the development of the incisor process, the maxilla covers in the intermaxillary bone, and in man prevents its maxillary protrusion. The nasal passage of either side is thus completed. By a growth of the second subaxial arch, the pterygoid and palatal bones are at this time outlined, the union in the middle line to form the palate, it may be noticed, taking place from before backwards; the palate bones joining in this direction at a later period than do the palatal processes, from the maxillae.

The third cleft (Fig. v, 3), forms the mouth, and is bounded by the third subaxial arch. This is an outgrowth from the cartilage, in which the internal ear is developed. In a foetus, nearly five-tenths of an inch long, the mandible (inferior maxilla), is united at its symphysis.

The fourth cleft (Fig. v, 4) is that for the auditory nerve, and is limited below by the outgrowth of the fourth subaxial arch. In a foetus half an inch long, it consists anteriorly of a thickened nodule; and so rapidly do the changes now under consideration progress, that in a foetus .55 of an inch long, this ill defined thickening has acquired the shape and

position of the tongue. In a foetus .9 of an inch long, this arch, which may be called the lingual, consists of a globular cartilage, connected with the periotic tissue below and behind the root of Meckel's cartilage (part of the mandibular arch). In a foetus 1.8 of an inch long, this arch consists of five portions, cartilage and membrane alternating; the lowest nodule of cartilage joining the hyoid arch, and constituting, in the adult, the lesser horn of the hyoid bone: from this the tongue rises.

It is not necessary here to refer in any detail to the remaining arches connected with the base of the skull: they are the hyoid, the laryngeal, and the exoccipital. In their development they follow the growth of the cerebral nerves; the most remarkable being, perhaps, that of the laryngeal, with its extension into the thorax, in association with the pneumogastric nerve, and the development, from the single tube of which it at first consists, of the larynx with the trachea, and of the lower part of the pharynx with the œsophagus. (For a description of these arches, see the *Philosophical Transactions*, 1871, p. 121, pl. i.)

If we take a cartilaginous base of the human skull, upon what must we consider that the fashion of its apparently irregular growth depends?

In a foetus 1.9 inches long, we see that the cartilage forms a central mass, from which, at various points, there are lateral outgrowths (Fig. vi). The central cartilage commences in front, with the flexure of the trabeculae, and, after dividing, to allow of the passage of the spinal cord, reunites and ends at the internal occipital protuberance. From around this cartilage, membrane extends to form the sides and vault of the skull; and of this membrane, the parts which have undergone chondrification on each side from before backwards are the following: 1. In front of and surrounding the optic nerve; 2. Beneath the optic nerve, and joining the preceding; 3. Behind No. 2, deeply notched in front, and posteriorly; 4. Surrounding the facial and auditory nerves. If we examine these outgrowths of cartilage with reference to the position of the cerebral nerves, we can but come to the conclusion that they are developed in connection with, and for protecting, the nerves. The relation in this sense of the olfactory with the trabeculae, of the optic with the presphenoid and orbito-sphenoid cartilages, and of the fissure of the exoccipital cartilage with the exit of the hypoglossal nerve, are evident.

The growth of the ala sphenoidalis (No. 3) leaves in its front a fissure for a group of nerves (Fig. vi, 3) [third, fourth, first and second of fifth, and sixth], and one of these, lying in a deep notch (Fig. vi, 4), the second branch of the fifth nerve, is at a late period shut off from the rest by closure of this notch in front; whilst at the back of the ala sphenoidalis, a second notch (Fig. vi, 5), which at first is common to the third branch of the fifth, the carotid artery (Fig. vi, 5a), the eighth pair of

Fig. 5.

Fig. 6.

Fig. 7.

nerves (Fig. vi, 7), and the jugular vein (Fig. vi, 7a), is modified by the closure of the notch to form the oval foramen, and by the outgrowth of the cartilage of the internal ear (Fig. vi, 6), which partially surrounds and diverts the course of the carotid artery, and which interposes between the foramen antierius and the foramen posterius, which previously formed parts of a common passage for nerves and vessels.

If the subaxial arches be followed in their growth, it will be seen how the cartilage, membrane, and bone, of which in parts and at times they are composed, mould themselves during development to the nerves they grow with. Thus the second division of the fifth determines the formation of the fissures at the back of the orbit, and keeps open the notch in the upper jaw, which does not become a foramen (infraorbital) until after the twenty-fourth week; the process from the frontal membrane ossifies over the nasal nerves; and the course of the anterior dental nerves determines the line of articulation between the maxillae and the corresponding intermaxillary bone (see *Philosophical Transactions*, 1869, p. 166); the provision, by divided growths from the ala sphenoidalis, for the nerves which descend between the palate, pterygoid, and superior maxilla; and, more remarkable than any, the outgrowth of the pneumogastric with the larynx and other structures with which it is functionally related, give further illustrations of the influence of the nerves in determining the growth of various parts.

THE HASTINGS PRIZE ESSAY,

1873.

ON THE PATHOLOGY AND TREATMENT OF OVARIAN DISEASES.

By LAWSON TAIT, F.R.C.S.,

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II.

THE ovaries are liable to certain displacements, which may give rise to many disagreeable symptoms without any actual disease of the glands. Thus one or other, or both, ovaries may, by a relaxation of their peritoneal investments, drop into the retro-uterine *cul-de-sac*, and there be sources of great trouble. This will be especially the case if there be at the same time retroflexion or retroversion of the uterus; for I have known such a displacement of an ovary to utterly prevent the application of any apparatus for the replacement of the uterus, and cause so much suffering as almost to make us discuss the question of ovariectomy. In such displacement, pressure on the gland gives rise to the same sickness and faintness as pressure on the testicle produces in the male, and the passage of a hard motion will give rise sometimes to most alarming symptoms. A more rare displacement of the ovary is forwards, this being generally an excess of embryonic transition, and it may be carried so far as to take the ovary into the labium, after the manner of the descent of the testicle. Cases of this kind are given by Oldham and Rigby; and Percival Pott (*Chirurgical Works*, by Earle, vol. ii, p. 210) actually removed both ovaries displaced in this way; and Dr. Meadows has removed one (*Obstet. Soc. Trans.*, vol. ii).^{*} Cystic degeneration is said to have occurred in this position, and a Spanish surgeon has recorded the removal of a cystic ovarian tumour from outside the inguinal ring. I have had no experience of this displacement.

Klob has described a twisting of the ovary on its axis which is probably congenital, and has not yet been found to be of any pathological importance in an otherwise healthy ovary. In the cystic ovary, a similar twisting has been observed to a more complete extent and with disastrous results. The ovary is sometimes completely detached from its normal position and relations, and forms new attachments elsewhere. This occurs with the healthy ovary, and, as Mr. Spencer Wells has shown, also probably after it has undergone degeneration. How and when it occurs have not yet been satisfactorily explained. In uterine procidentia and prolapse, corresponding displacement of the ovaries occurs.

There is a large class of ovarian disease due to altered hæmic nutrition of the gland, which clinical experience proves to be far more common than pathological investigation has yet shown. Of the prime factors in these cases we are as yet ignorant; but, clinically, they range themselves naturally into three groups, differing probably only in degree of severity, save in the cases where acute ovaritis has a specific origin. They are:

- I. Ovarian Hyperæmia.
- II. Chronic Ovaritis.
- III. Acute Ovaritis.

It may seem a metaphysical refinement to make a distinction between the first and second of these classes, but I have long satisfied myself that it actually exists. Ovarian hyperæmia is the result of an over-sufficient and generally precocious ovarian activity, and is, therefore, the converse of the condition I have detailed under ovarian amenorrhœa and dysmenorrhœa. It is far from being a rare affection, and is invariably well marked in its history, the chief detail of which will generally be found to be menorrhagia. In a typical case which I have now under my care, the following is a summary of the facts. The young lady is the child of parents of markedly nervous temperament, is well-grown, I might almost say prematurely developed in every way, and, when little over 13, began to menstruate. From the first, her periods were profuse and at first painless. She enjoyed excellent health for many months after the accession of menstruation, during which time the flow con-

^{*} I have now to add a hitherto unrecorded displacement of the ovary in a case where it had become developed at the umbilicus during embryonic life and become cystic, and from which situation I successfully removed it.—May 18th.